3. REMEDIAL ACTION PHASE WORK DESCRIPTION

At the completion of 2 years of phytoremediation, the WAG 9 managers made the decision to proceed with phytoremediation activities as described in this Remedial Action Report. The decision was based on verification results documented in the phytoremediation 2-year field season demonstration project report (DOE 2001). A hybridization of the selected and contingent remedies was implemented for the individual sites after the interim remedial action report was submitted. This hybridization between phytoremediation and excavation and disposal would be based on the success or failure of phytoremediation of specific contaminants at the various sites. The final decision of phytoremediation and/or excavation and disposal was a mutually agreeable decision between the Agencies for each site. Deviations from the primary remedy selected in the OU 9-04 ROD, phytoremediation, are documented in two ESDs (DOE 2000, 2004). The specific work activities conducted during phytoremediation and excavation and disposal efforts completed at the MFC are described in the following subsections.

3.1 Phytoremediation

The phytoremediation effort at the MFC took place between 1999 and 2003, at which time final soil samples were taken to determine if the RGs, as identified in the OU 9-04 ROD, had been met.

The following subsections describe the activities associated with the removal of contaminants via phytoremediation at MFC.

3.1.1 Preplanting Activities

Preplanting activities involved grubbing of currently existing vegetation, grading, removing rock, and installing irrigation lines, fences, and signs (where necessary). Each of the activities specific to the phytoremediation of contaminated soils are discussed below in further detail.

3.1.1.1 Grubbing Activities. Many of the sites contained dead cattails and reeds stalks from previous years' growth prior to the implementation of phytoremediation. These plant remnants had been knocked down to the bottom of the ditch by the winter snows. This preexisting growth was not removed for disposal during grubbing activities.

3.1.1.2 Grading Activities. A grader and a small front-end loader were used (where necessary) to slope the areas at approximately a three-for-one foot grade to allow for equipment access to all phytoremediation sites.

The ICM originally consisted of irregular mounds along the bank of the Interceptor Canal, which varied in width and depth. To facilitate growing plants in a controlled and engineered methodology that optimized exposure of the cesium-soil-root interphase, the mounds were graded to form a rectangular plot approximately 2 ft thick, 40 ft wide, and 500 ft long. The surface of this area was also sloped approximately 2–4% to the west to prevent the ponding of water between the Interceptor Canal ditch banks and the area undergoing phytoremediation.

A man bridge and two vehicle bridges cross the IWLSDD that impeded the work and grading activities being conducted at the IWLSDD. In addition, computer control lines, electrical lines, and two industrial waste water discharge pipes limited the grading activities around the man bridge area.

3.1.1.3 Rock Removal. Rocks larger than a cobble (2–3 in.) were removed manually using a steel rake prior to planting. These rocks were not native to this area and were historically used as ground cover

over open areas. Over time, the rocks were dislodged and moved to the ditch bottom. The rocks had no contamination on their outer surfaces and were placed on the outer edges of the ditch banks.

3.1.1.4 Barrier Installation. Where necessary, measures were taken to prevent human exposure to the contaminated sites. Signs were placed on fences around each area that identified the area as a CERCLA site undergoing phytoremediation and also identified a point of contact. The signs were placed approximately every 50 ft along the ditch banks, which minimized the potential for inadvertent human entrance into the phytoremediation sites. A minor human intrudance would not have posed an unacceptable human risk because the unacceptable risks to human receptors are for a minimum exposure of 8 hours per day for 20 years.

Ecological receptors that could potentially have gained access to these areas were small mammals, insects, and birds. The small localized population exposure to these areas during phytoremediation activities did not have any detrimental effect to the population of these animals on INL, Eastern Idaho, or the State of Idaho.

3.1.2 Planting Activities

3.1.2.1 Inorganic Contaminants. Those sites that had inorganic contaminants (the west portion of the MCTBD and the IWLSDD) were initially planted with 3-ft-tall, bare-root Prairie Cascade Willows (*Salix x pendula*). These trees were replaced with the hybrid poplar due to a shortage of willow trees in 2001. Trees were spaced approximately 18 in. on center to optimize the biomass of the plant at the end of the field season. The holes for the trees were either made manually using a spade or using a hydraulically driven auger mounted on a boom (see Figure 9). The holes were excavated to approximately 12 in. into the soil to allow for complete planting of the roots. The soils were placed back into the hole and lightly tamped. The trees were watered to allow for settling of soil around the roots and to reduce the amount of void space. Where the tractor was not able to reach a planting location, the willow trees were manually planted using a shovel to dig the hole.

When subsurface rock was encountered, the hole location was moved toward the center of the ditch. The center of the ditch contained the contamination; keeping the plants closest to the ditch center maximized the potential for contaminant removal. It was important to try to complete the planting as close as possible to the grid to limit the potential for stunting plant growth, which would reduce the biomass produced, and ultimately, contaminant removal.

At several grid locations the underlying basalt layer restricted the planting depth to less than the required depth of 12 in. Trees were planted at these shallow locations only if a depth of 6 in. could be reached; in these cases, a larger diameter hole was required to accommodate the root ball. If a planting depth of 6 in. could not be reached, the location was bypassed for the next grid location.

Because the contaminants would be sequestered in the roots of the willow, the roots would have to be harvested to permanently remove the contaminants from the soil. As the roots of large trees would be problematic to remove, it was determined that smaller trees should be planted in close proximity to maximize the removal potential of the willows. The willow trees were grown for a 2-year period to allow the roots to better penetrate the soils prior to harvesting in the fall of the second year. However, heavy rains in May and June caused surface water runoff of residual herbicides that affected the size and number of willow trees that survived the first field season. Those trees that did not survive the first field season were not immediately replaced as it was believed that residual concentrations of the herbicide were still present in the soil.

The first crop of willows was removed in their entirety at the end of the second field season and plans were made to plant a new crop of willows the following spring. However, willow saplings were in short supply at the commencement of the third field season and it was determined that the hybrid poplar tree would serve as an adequate substitute. Over the next 2 years, the poplar trees grew rapidly with intermittent problems associated with an increase in soil pH, which was remedied with a soil acidifier. The second crop of poplars was removed in its entirety at the end of the fourth field season.

Figure 9. Planting of willows.

3.1.2.2 Radioactive Contaminants. Those sites that contained radioactive contaminants (ICM and Ditch A) were planted with kochia (*Kochia scoparia*). The optimal spacing of the kochia was determined to be approximately 4 in. on center. The soil was prepared prior to planting using a ripper to loosen the soil to approximately 20 in. deep. A plow was then used to turn over the soil and further enhance the air to soil contact. A rototiller was then used to prepare the seed bed prior to planting. It was also anticipated that tilling would mix the soil for a more homogenous soil contaminant profile. The area was then watered every day (in manual mode) until the kochia plant roots were established and able to sustain an increase in water supply.

Seeds were planted the first field season using a hydroseeding truck equipped with a tackifier to distribute the seeds in a paper-mulch/water/fertilizer mixture (see Figure 10). This method of seeding proved problematic as the paper-mulch formed a hard crust once dried, which inhibited the emergence of the kochia sprout. During the second field season, kochia seeds were broadcast by hand with much improved results. The kochia seeds were able to sprout faster, which allowed for harvesting twice in one season. The successful increase in biomass production observed in the second field season was mirrored in the third and fourth field seasons when seeds were similarly hand broadcast. In each field season where a dual harvest was practical, the first crop of kochia was cut at a height of 2 in. from the ground and the second crop allowed to regrow from the remaining roots. The second crop was then removed in its entirety at the end of each field season.

Figure 10. Application of kochia seeds via hydroseeding.

3.1.3 Irrigation and Amendments

For phytoremediation to be successful, additional water was required to fully optimize the removal efficiencies of the plants. To accomplish this, the MFC utilized supplemental irrigation to water each phytoremediation site. The irrigation system was designed to allow for automatic watering with a manual override to either stop or start watering. The system used untreated groundwater in the MFC fire suppression system as the irrigation source; all distribution lines originated in a centralized location near the MFC Cooling Tower (see Figures 11 and 12). The distribution lines were located on the top of the south and west ditch banks. This allowed for minimal wind drift losses from the typical southwesterly winds. The selected irrigation heads were commercially available home sprinkler lines, which were fully adjustable from 0–180 degrees with a range of 15 ft. The heads were placed on risers with Nelson 30-lb pressure regulators to keep water rates consistent between the irrigation heads. Each head was spaced 15 ft apart to allow for double coverage with each head. The selected irrigation line was commercially available 2-in. poly line. Saddles were inserted into the poly line at the desired sprinkler-head location. A threaded riser was screwed into the saddle and regulator, and then the sprinkler head was attached. The risers were anchored into the soil to prevent the wind from knocking them over. The irrigation line was slightly trenched into the ditch bank to minimize rotational movement and reduce the tripping hazard.

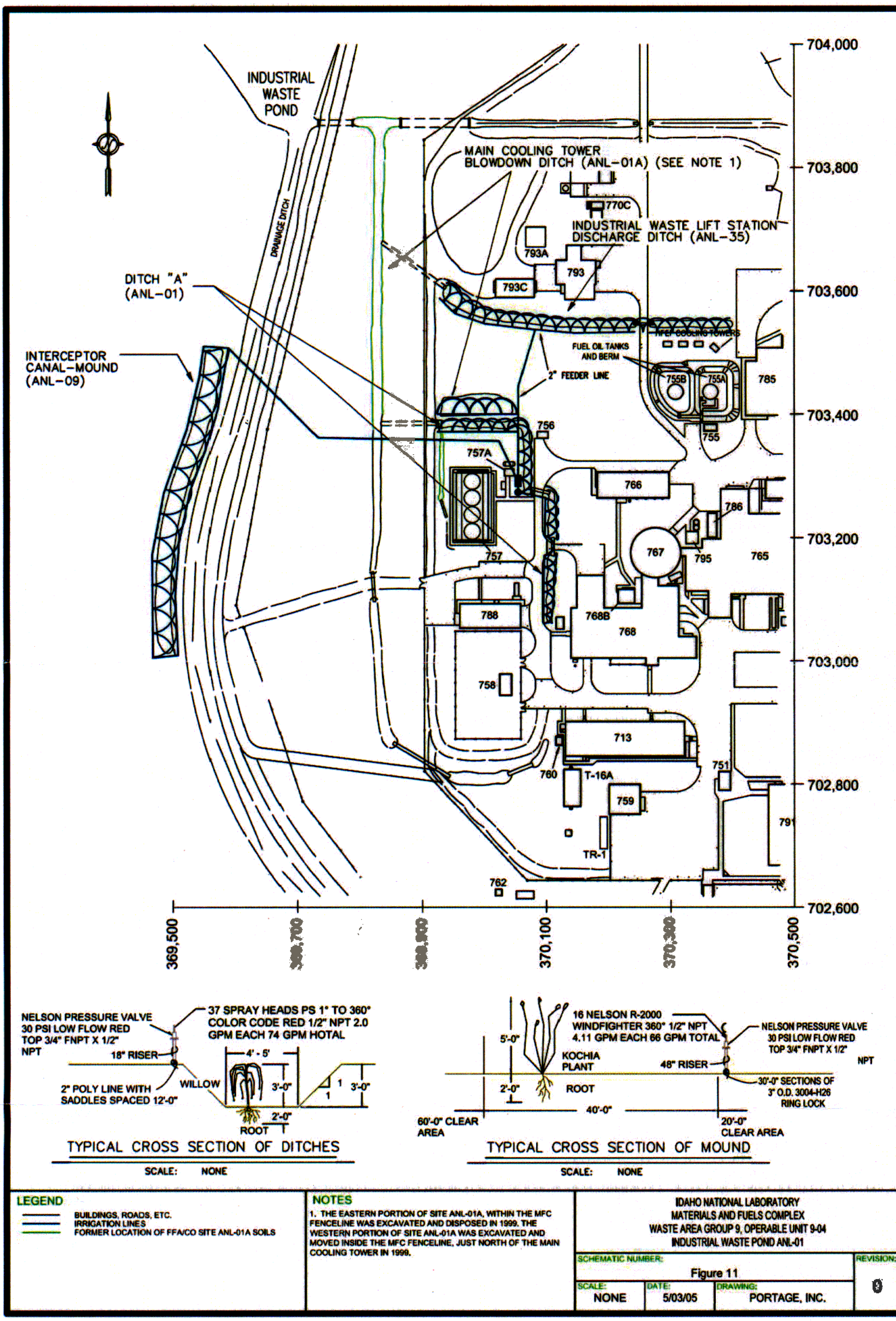

Figure 11. Irrigation system location.

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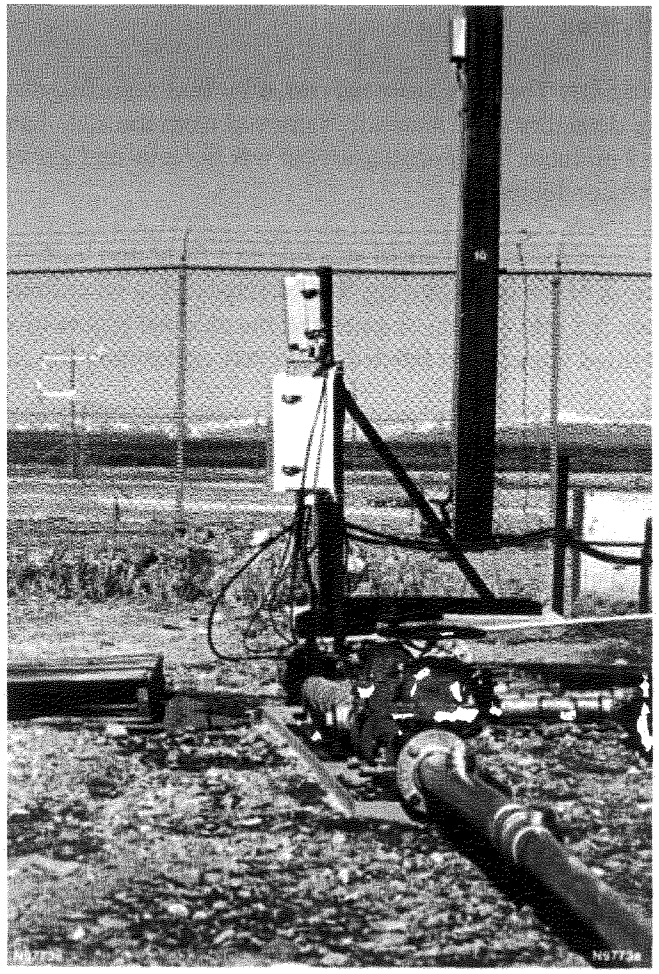

Figure 12. Irrigation water system header.

Efforts were made to maintain the soil moisture content at the optimal range of 40–50% in the contaminated zone. Moisture detectors were installed that could automatically turn on or shut off the irrigation system as the soil moisture varied outside these levels. Two moisture detectors were stacked vertically at depths of 1.0–1.5 ft. An automatic watering switch was installed on the detector located at the 1.0-ft depth. This was utilized to "train" the willow plant roots to stay within the contaminated zone as they seek out the water. The lower moisture detector was used to verify that irrigation had not leached the contaminants below the contaminated zone. The system was adjustable to optimize the moisture content required by each individual site. Calibration of the moisture detectors along with the moisture content set point adjustments were made in the field.

The system could also be manually overridden if it was determined that more or less water was required for an individual site. A pressure reducer and chemical injection system were installed prior to the distribution lines. This allowed the MFC to add soil amendments (such as fertilizers and/or extractants [ethylenediaminetetraacetic acid and citric acid]) to each of the waste sites through the irrigation system. Nutrient analysis of the soils was performed periodically and the necessary fertilizers were applied to meet the needs of the plants through their growing season. The chemical injection system was only operated after the root zone fully covered the contaminated area and then only in the manual mode.

3.1.4 Harvesting Activities

3.1.4.1 Willow and Poplar. The trees were harvested by first reducing the moisture of the soil to less than 30%. The moisture detectors were manually removed from the soil. The irrigation system was then manually operated for 5 minutes. The purpose was to wet the area and act as a dust suppressant while the harvesting activities were conducted.

Harvesting was accomplished using a chain attached to a front-end loader. The other end of the chain was attached to the trunk of the tree allowing it to be removed in its entirety from the soil (see Figure 13). The tree was then fed into a wood chipper and the chipped pieces of wood were funneled into 4- by 4- by 8-ft boxes. The filled boxes were labeled, surveyed, and staged for disposal at the CFA Industrial Waste Landfill.

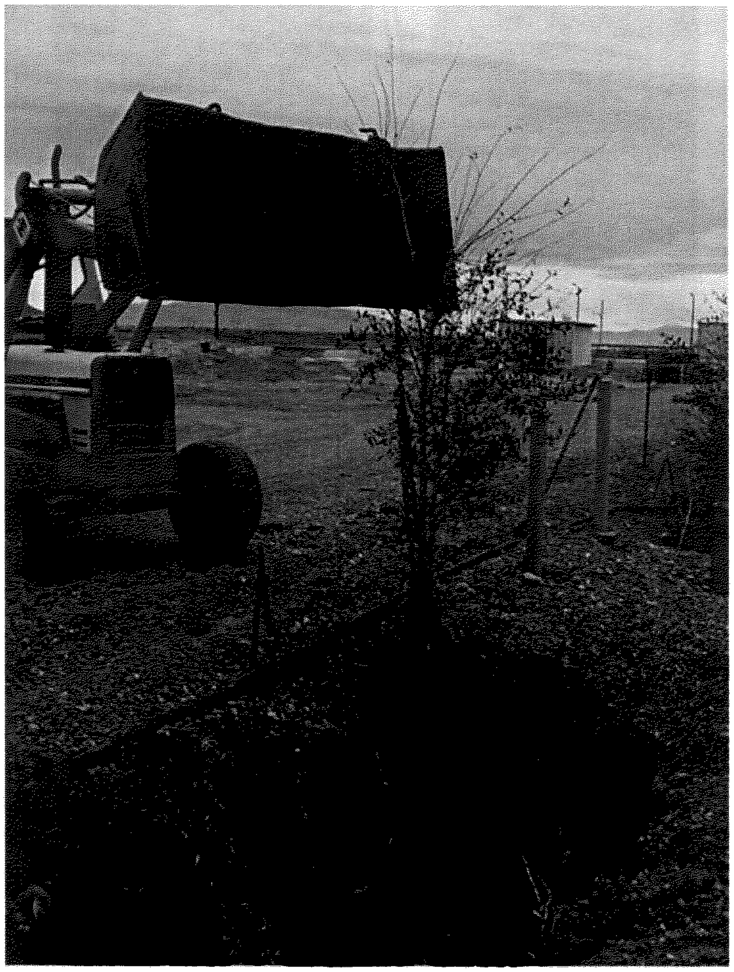

Figure 13. Harvesting of trees.

3.1.4.2 Kochia. The kochia was harvested as soon as the first flowers on the plants were evident, which prevented seeds from developing and being released across INL. As mentioned previously, when two harvests were made in one growing season, the first harvest consisted of mowing the kochia to an approximate height of 2 in. and allowing the roots to regrow foliage. The second harvest included the removal of the plant in its entirety. If a second harvest was not feasible due to time constraints, the kochia was removed in its entirety at the end of the growing season.

The kochia harvest was initiated by reducing the moisture of the soil to less than 30%. The moisture detectors in the soil were then manually removed from the soil and the irrigation system was operated for 5 minutes. This wet the area and acted as a dust suppressant while harvesting activities were being conducted.

If the kochia was to be cut in lieu of complete removal (two harvests in one season), the foliage was harvested using a commercially available, walk-behind cycle mower, which had a 4-ft-wide mowing bar that cut the kochia approximately 2 in. above the ground. The kochia foliage was allowed to dry in place until the moisture content was approximately 20% and then raked into windrows using a commercial hay rake. The kochia continued to dry until the moisture content was approximately 15%, at which point it was baled. Each bale was surveyed, loaded onto a small utility trailer, and transported to a staging area inside the MFC facility.

If the kochia was to be removed completely (at the end of each field season), a two-row potato digger was used behind the tractor to lift the plants to the surface (see Figure 14). A rake was then used to pile the plants into windrows, which were allowed to dry to a moisture content of approximately 15%. At this point, the plants were baled (see Figure 15). Each bale was surveyed, loaded onto a small utility trailer, and transported to the Radioactive Waste Management Complex (RWMC) for disposal following the INL Reusable Property, Recyclable Materials, and Waste Acceptance Criteria (RRWAC) (DOE-ID 2005). These shipments are documented in the Integrated Waste Tracking System.

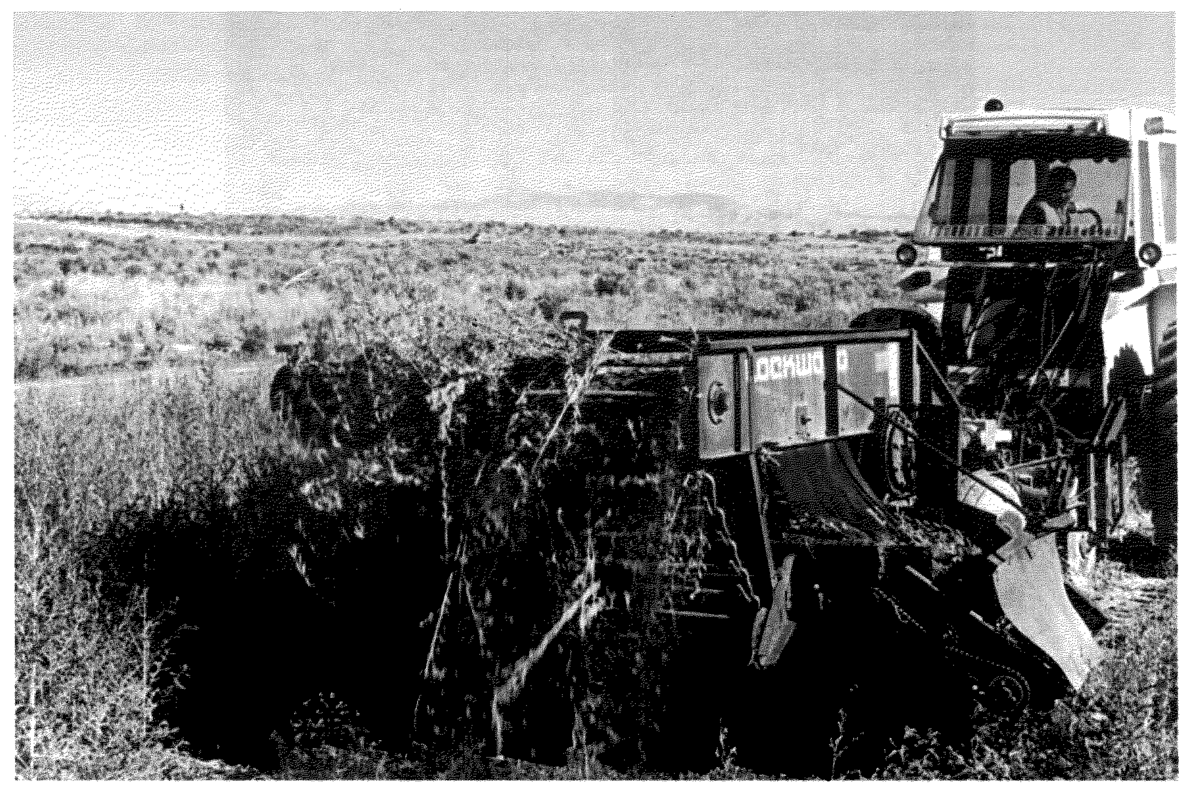

Figure 14. Complete removal of kochia with a potato digger.

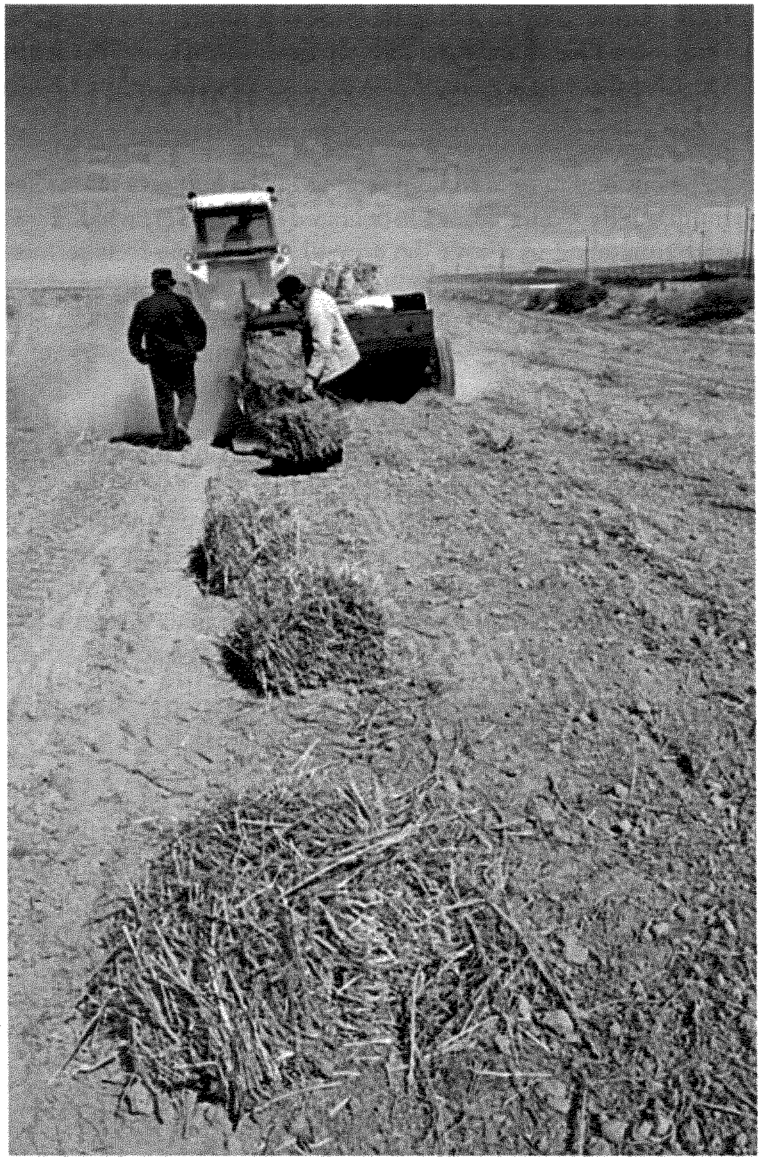

Figure 15. Bailing of kochia during harvesting activities.

3.1.5 Post-Harvesting Activities

After each field season, post-harvesting activities were initiated that included regrading the soils back to the original preplanting cross-sectional requirements. The irrigation line was turned off at the fire hydrant and the distribution line pressurized to 50 psi using a portable air compressor. Each of the distribution lines were manually activated to blow the water from the irrigation line. This was completed for each distribution line to prevent water from breaking lines during the winter.

3.1.6 Disposal

The harvested plants associated with the phytoremediation effort at the MFC were formed into bales, dried, and disposed. The disposal of plant material used in the phytoremediation of radioactive contaminants was in accordance with the INL RRWAC (DOE-ID 2005). The disposal of plant material used in the phytoremediation of inorganic contaminants was in accordance with the specifications for conditional wastes found in Subsection 4.3.2 of the RRWAC (DOE-ID 2005). The MFC followed internal instructions in accordance with Subsection 6.3 of Section 3.1, "Shipment of Radioactive and Nonradioactive Items of Equipment, Material, and Hazardous Wastes," of the *ANL-W Environmental Safety and Health Manual* (ANL-W 2003). The MFC also submitted the appropriate forms to the INL managing contractor and received signed concurrence prior to shipment. The volumes of biomass generated during the phytoremediation effort at the MFC, as well as the disposal location, are listed in Table 2.

Table 2. Volume of biomass generated during phytoremediation.

Year	Biomass	Site	Volume Removed (yd^3)	Disposal Location[a]
1999–2000[b]	Kochia	ICM and Ditch A	11	RWMC SDA
2001–2002[c]	Kochia	ICM and Ditch A	18	RWMC SDA
1999–2002[d]	Willow/Poplar	West MCTBD and IWLSDD	24	CFA Landfill

a. Holzmer, M., to W. Pierre and D. Hygard, November 19, 2002, "Suitability Determination for Disposal of WAG 9 Phytoremediation Plant Matter at the INEEL Central Facilities Landfill and RWMC."

b. Integrated Waste Tracking System, Materials and Waste Characterization Profile, "Compactable LLW Vegetation," 2334P, March 1, 2000.

c. Integrated Waste Tracking System, Materials and Waste Characterization Profile, "Dried Vegetation from Phytoremediation," 2334P.R1, December 6, 2001.

d. Integrated Waste Tracking System, Materials and Waste Characterization Profile, "Willow Trees Removed from CERCLA WAG 9 Area," 3345P, July 3, 2002.

The kochia harvested from the ICM and Ditch A was disposed in the RWMC Subsurface Disposal Area (SDA). The kochia sequestered only radioactive cesium-137 from the contaminated soil. Levels of this COC were measured at seven orders of magnitude less than the RWMC waste acceptance criteria (WAC) (5,360,000 pCi/g). The plant material did not contain any other hazardous compounds.

The willow and poplar trees harvested from the west portion of the MCTBD and the IWLSDD were disposed in the CFA landfill. Although these trees were used to remove inorganic contaminants from contaminated soil, levels of these COCs in the harvested trees met the CFA WAC and were well below concentrations that would have presented a threat to the underlying aquifer.

3.2 Excavation and Disposal

The selected remedy for the MFC OU 9-04 sites, as stated in the ROD, was phytoremediation, but observed results over time indicated that several sites contained contaminants at concentrations that could not be remediated via phytoremediation in a timely manner; therefore, the alternate method of excavation and disposal was employed. The remedial activities associated with the excavation and disposal of the contaminated soils at the MFC OU 9-04 are discussed in the following subsections.

3.2.1 Preexcavation Activities

Preexcavation activities involved compiling analytical results of all characterization sampling. Characterization sampling results were copied from the WAG 9-04 Comprehensive RI/FS (Lee et al. 1997) and attached as supplemental information to the required INL managing contractor's documentation packages.

The first step in the soil excavation was to mark all existing underground utilities (such as fire hydrant supply lines, water supply lines, sewer lines, buried electrical lines, overhead power lines, cathodic protection lines, and security warning devices) within 50 ft of the excavation area. This was accomplished using existing site drawings and onsite inspections by key plant services personnel and safety engineers. The MFC completed the digging/excavation permit in accordance with Section 4.4H of the *ANL-W Environment, Safety, and Health Manual* (ANL-W 2003). Temporary stands were spaced approximately 50 ft apart around each area to set up a contaminant reduction zone. The temporary stands had ring hangers approximately 3 ft off the ground that were used to string a yellow and black poly rope between the stands. Signs were attached to the rope warning people that only authorized personnel are allowed in the contaminant reduction zone. The surface soils were wetted using a garden hose and sprayer attachment to control dust during excavation activities. Watering and rewatering occurred whenever the exposed surface was dry and susceptible to wind erosion.

Prior to initiating the remediation effort, a safety meeting was held for all workers to define the hazards associated with the removal action. The workers donned Occupational Safety and Health Administration (OSHA) Level D personal protective equipment (PPE). As a minimum, the PPE consisted of leather shoes, leather gloves, safety glasses, hardhats, and coveralls. In addition, no eating, drinking, smoking, or gum chewing were allowed in the contaminant reduction zone.

3.2.2 Excavation Activities

The excavation of soil was conducted using a front-end loader and dump truck. A laborer assisted the front-end loader operator in the use and control of the bucket (see Figure 16). The excavated material was placed in the dump truck stationed on the road just west of the ditch. This process was repeated until the front-end loader had excavated as much soil as possible from the contaminated ditch. The laborers then used shovels to manually remove the remaining soils in the ditch and place them in the front-end-loader bucket. The laborers then used shovels and brooms to remove as much soil as possible from the top of basalt in the ditch bottom.

Figure 16. Excavation activities at the Industrial Waste Pond.

When a dump truck was filled, it was carefully inspected to remove any additional material accidentally deposited on the outside of the truck box. Any soil removed from the outside of the truck box was placed into the dump truck. The dump truck was driven out of the contaminated zone over to Building 783, where a tarpaulin cover was attached to prevent loss of material during transit. Officials at the CFA Industrial Waste Landfill were then notified of a pending shipment; completed documentation accompanied the shipment. When all soil had been shipped or prior to the dump truck being used for other non-CERCLA jobs, the truck was washed at the cooling tower decontamination wash pad.

The cooling tower decontamination wash pad consisted of a concrete bermed area that is sloped to a centralized drain. A high-pressure washer was utilized, along with shovels and brooms, to remove residual ditch soil from the truck. Large debris and/or material firmly attached to the truck was removed using a shovel or a scrub brush. After being washed, the dump truck was moved off the wash pad and moved to Building 783. The laborers washed the scrub brushes, shovels, brooms, and other equipment used with the high-pressure washer. These tools were air dried and returned to the tool crib. Laborers also used the high-pressure washer to clean the wash pad of all soil residues.

The wash pad fluids were drained into the catch basin and then pumped into the oil/water separator where a majority of the liquid evaporated. The remaining liquid from the oil water separator was pumped into a poly drum that was staged on the wash pad until the completion of remedial activities. At the time of disposal, this drum was sampled and analyzed for pH. Results were within RCRA limits and the drum was disposed in the IWLSDD.

3.2.3 Disposal

The volume of soil removed from each site as well as the disposal location are listed in Table 3.

Table 3. Volume of soil removed and disposal location.

Year	Site	Volume Removed (yd^3)	Disposal Location
2000[a]	East MCTBD and Ditch B	160	CFA Industrial Waste Landfill
2004[b]	IWLSDD and Ditch A	136	CFA Industrial Waste Landfill
2004[c]	IWP	1440	ICDF Landfill

a. Integrated Waste Tracking System, Materials and Waste Characterization Profile, "Soil from Main Cooling Tower Blowdown Ditch and Ditch B," 2550P, July 6, 2000.
b. Lee, S., to H. Guerrero, January 28, 2005, "Fw: ANL-W Interior Ditch Soils."
c. Lee, S., to H. Guerrero, April 28, 2005, "Fw: Attachment: MFC to ICDF Landfill MP 4243P."

Excavated soils were shipped to the CFA Industrial Waste Landfill as conditional waste or the ICDF. The specifications for conditional wastes are found in Subsection 4.3.2 of the RRWAC (DOE-ID 2005). The MFC followed internal instructions in accordance with Subsection 6.3 of Subsection 3.1, "Shipment of Radioactive and Nonradioactive Items of Equipment, Material, and Hazardous Wastes," of the *ANL-W Environmental Safety and Health Manual* (ANL-W 2003). The MFC also submitted the appropriate forms to the INL managing contractor and received signed concurrence prior to shipment.

3.2.4 Confirmation Sampling

Confirmation samples are typically collected after the site has been remediated to show that the RGs established in the OU 9-04 ROD have been attained. Confirmation soil samples were collected, where practicable. In several instances, all soils were removed to the underlying basalt layer as part of excavation and disposal activities (see Figure 17). Therefore, collection of soil samples in these areas was not practicable and it was agreed with the Agencies that previous confirmation sampling activities and results would be used, in conjunction with complete soil removal, to demonstrate that the RGs had been met.

3.2.5 Regrading

In November 2004, following the removal of contaminated soil to the exposed bedrock to meet the RGs, each site was regraded. Clean backfill material was trucked from the borrow pit located 2 miles northwest of the MFC. The backfill material was applied in approximately 4-in.-deep lifts, and compacted using the tires and weight of the front-end loader and gas-powered hand tampers around the culverts. A scraper was utilized to blade the bottom and side-slopes of the ditch to its original shape.

Figure 17. Underlying basalt layer.

3.2.6 Revegetation

Those sites located near the fenced area were not revegetated (i.e., MCTBD, IWLSDD, Ditch A, and Ditch B). Not only will these ditches continue to carry both industrial waste water and storm water runoff in the future, excessive vegetation at these sites would create security issues at the MFC site.

The revegetation of the IWP and ICM was initiated in November 2004. Both sites were seeded with a seed mixture composed of native grass species (Table 4). The IWP was seeded above the anticipated water level (see Figure 18); the ICM was seeded in its entirety (see Figure 19). A straw cover was applied at the ICM and tamped into the soils. Both sites were seeded with a fertilizer mixture distributed by a broadcast system.

Table 4. Native grass seed mixture components.

Species[a]	Scientific Name	Rate of Application (lb/acre pure live seed)
Indian Rice Grass	*Achnatherum hymenoides*	2
Thickspike Wheatgrass	*Elymus lancolatus ssp. lanceolatus*	2
Streambank Wheatgrass	*Elymus lancolatus ssp.*	2
Bluebunch Wheatgrass	*Pseudoroegneria spicata ssp. spicata*	2
Munro Globemallow	*Sphaeralcea munroana*	1
Northern Sweetvetch	*Hedysarum boreale*	1
Wyoming Big Sagebruch	*Artemisia tridentata ssp. wyomingensis*	0.5
Green Rabbitbrush	*Chrysothamnus viscidiflorus*	0.5

a. SOW-691 (2003).

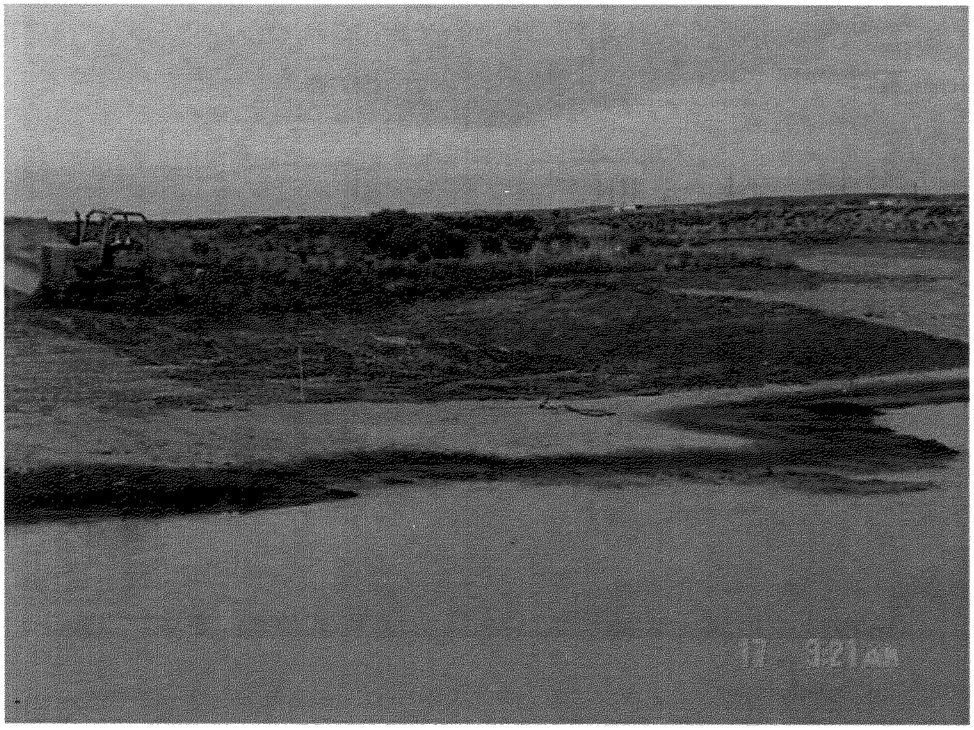

Figure 18. Revegetation of the IWP. Area of additional soil renewal shown in the center of the photograph.

Figure 19. Revegetation of the ICM.

Although ongoing operation and maintenance of the revegetated areas is not part of the remedy for either the IWP or the ICM, an annual inspection will be conducted in the fall, beginning in 2005, as agreed to by the Agencies. The annual inspection will identify areas that require additional maintenance or reseeding. Any additional seeding, as identified in the annual inspection, will be applied in the fall to allow the seeds to overwinter and germinate in the spring. The irrigation activities associated with the phytoremediation effort will not be continued during ongoing reseeding activities; the goal of reseeding is to reintroduce self-sufficient native grasses in a natural setting so as to reduce the likelihood of soil erosion. The annual inspection will continue until it is determined that native grasses have become well established in the revegetation areas.

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